Cooler Gas in Double-Barred Galaxies with Centrally Concentrated Molecular Gas Distributions

Glen Petitpas & Christine Wilson

Dept. of Astronomy
University of Maryland
College Park MD 20742

Dept. of Physics & Astronomy
McMaster University
Hamilton ON L8S 4M1

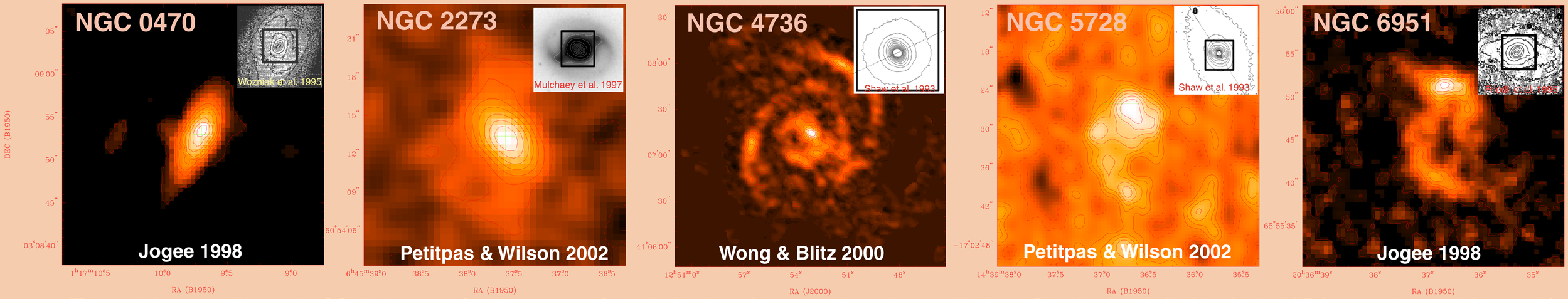

Figure 1: Integrated intensity CO J=1-0 maps for the centers of 5 galaxies thought to contain nuclear stellar bars. Despite the similarities in the NIR images (upper right panels) the CO maps show a wide variety of distributions. The NIR images of these galaxies show evidence for nuclear stellar bars, while the similarities in these images suggest that the gravitational potentials are similar. The green "+" on the CO maps marks the dynamical center used in the radial profiles. The black box on each NIR image represents the approximate area shown in the corresponding CO map.

Motivation:

We have performed a high resolution CO J=1-0 study of the nuclei of galaxies thought to contain a nuclear stellar bar, in addition to the galaxy's primary bar. The CO maps show a wide variety of morphologies (see Figure 1) despite the similarities in the NIR images (hence, the gravitational potentials).

One possible explanation for this is that the molecular gas may contain different physical properties that allow it to respond differently to the similar gravitational potentials.

To test this hypothesis we have performed a multi-transition CO study with the James Clerk Maxwell Telescope. We have *beam matched* ^{12}CO J=2-1, J=3-2 and ^{13}CO J=2-1 spectra for 7 galaxies, only five of which have high resolution CO maps published.

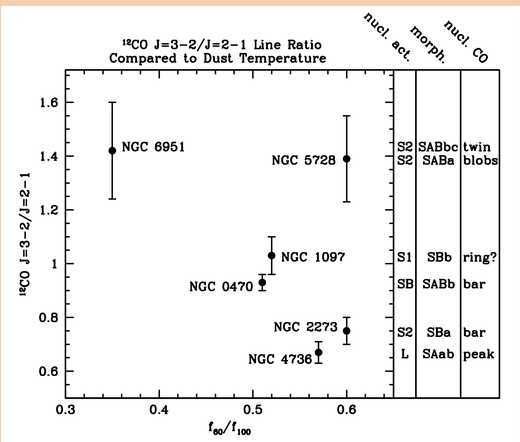

Figure 2: CO line ratios compared to IRAS dust temperature, nuclear activity, bar strength, and nuclear CO morphology.

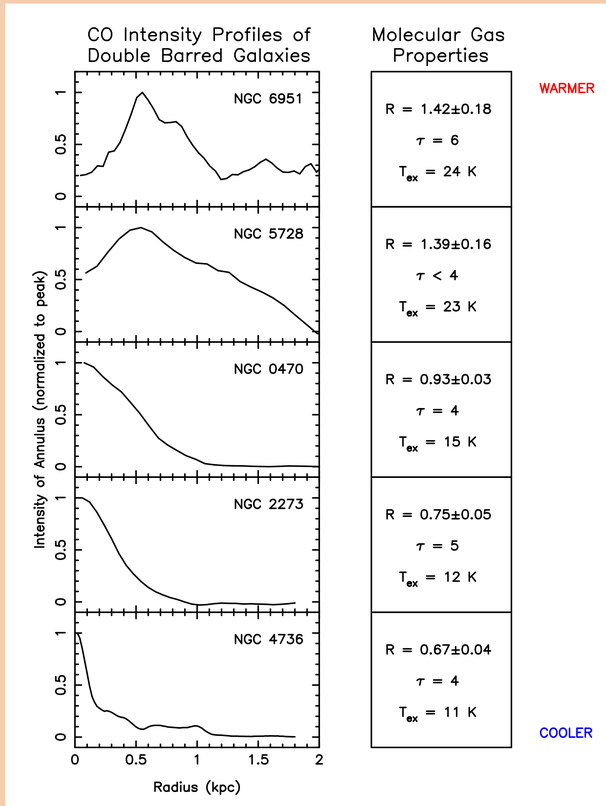

Figure 3: Azimuthally averaged CO J=1-0 profiles for a sample of double-barred galaxies compared to gas properties. R is the CO J=3-2/J=2-1 line ratio, is the optical depth of the gas. Since the optical depths are similar, the CO J=3-2/J=2-1 line ratio is probing gas temperature or density. T_{ex} is the gas excitation temperature assuming Local Thermodynamic Equilibrium.

Results:

We find that the ^{12}CO/^{13}CO J=2-1 line ratio is similar for all galaxies which suggests that the molecular gas has ***similar optical depths*** in each galaxy. This indicates that the ^{12}CO J=3-2/J=2-1 line ratios are tracing gas physical conditions and are not influenced by variations in optical depth between these galaxies.

Figure 2 shows that there is ***no correlation between the gas properties (as traced by the CO J=3-2/J=2-1 line ratio) and IRAS dust temperature, main bar strength, or nuclear activity***. There is evidence that the CO line ratio is lower in galaxies that contain centrally concentrated molecular gas distributions (either bars or central peaks). This result is emphasized in Figure 3.

Comparing the radial distributions with the gas properties (Figure 3) ***we find that galaxies containing more centrally concentrated CO distributions also contain cooler molecular gas***. There are at least two scenarios that may explain this:

a) Past nuclear star formation has heated and dispersed the molecular gas in the centers of some galaxies leaving a warmer more dispersed distribution of gas; or

b) The cooler gas is has a higher tendency to clump together and get transported into the nucleus of these double barred galaxies.

More detailed studies of the dynamics and star formation histories of these and similar galaxies in conjunction with more advanced models of double-barred galaxies are needed to verify/explain this result.

References:

Friedli, D., et al. 1996, A&AS, 118, 461
Jogee, S., 1998, Ph.D. Thesis, Yale University
Mulchaey, J., Regan, M., & Kundu, A., 1997, ApJSS, 110, 299,
Petitpas, G., & Wilson, C., 2002, submitted to ApJ
Shaw, M., Combes, F., Axon, D., & Wright, G., 1993, A&A, 273, 31
Wong, T., & Blitz, L., 2000, ApJ, 540, 771
Wozniak, H., Friedli, D., Martinet, P., & Bratschi, P., 1995, A&AS, 111, 115